**Defense Modeling and Simulation Office**
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# M&S Data Engineering Technical Framework (M&S DE-TF)

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## Revision History

| Revision | Date | Author | Description |
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| 0.1.0 | DEC 96 | Jack Sheehan, et al | initial draft |
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# 1. Introduction

## 1.1 Purpose

This paper specifies the Modeling and Simulation Data Engineering Technical Framework (M&S DE-TF). Within the Modeling and Simulation Common Technical Framework [1], the M&S DE-TF is:

- the formal vehicle for promulgating and enforcing data standards, and
- a template for using data standards to create, manage, and deliver data .

In particular, the DE-TF (Figure 1) provides data:

- recognition through common semantics and syntax,
- realization through data systems architecture,
- repeatability through a closed-loop engineering process
- reuse through standard data products, and
- standards through M&S functional data administration .

## 1.2. Applicability

The M&S Data Engineering Technical Framework version 0.2 applies to all DMSO sponsored organizations, products, and activities within the scope of the DoD Directive 5000.59 Modeling and Simulation Master Plan [1].

## 1.3. Organization

This specification of the M&S Data Engineering Technical Framework is organized as follows. Section 1 introduces the DE-TF. Section 2 provides an overview of the fundamental concepts and components of the framework. Section 3 provide a detailed expositions of the DE-TF products and processes. Lengthy expositions or extended examples are provides as enclosures. References, figures, and tables are collected in to Sections 4, 5, and 6, respectively. Section 7 provides a DE-TF specifications compendium. Where appropriate, technical derivations or detailed trade-studies are referenced as external documents. Specific data standards which provide formal Interface Design Descriptions (IDD) are referenced as external annexes to this document.

## 1.4. Objectives

The traditional DoD M&S product development and delivery paradigm enforces a rigorous, top-down procedure where:

- requirements are derived from specific operational needs,
- designs are derived from requirements, and
- custom components are created to implement the design.

While producing individually excellent products, this exclusively top-down procedure leads to stove-piped M&S solutions with these undesirable side-effects:

- limited interoperability and re-use between independently conceived products,
- reduced credibility of results when the stove-pipe does not include key communities, and
- response to changing requirements can be costly in time, resources, and quality.

A fundamental objective of DoD Directive 5000.59 is to address these undesirable side-effects by developing the infrastructure required for composable solutions. Composable solutions employ the principle of design inversion where:

- requirements are derived from specific operational needs,
- families of standard plug-and-play components are retained in a repository, and
- specific designs are created to meet the requirements using existing components from the repository.

In particular, the DoD M&S Master Plan [1] has directed the development of an M&S Common Technical Framework (Objective 1), authoritative representations of the environment, units and systems, and human behavior (Objectives 2-4), and infrastructure (Objective 5)required to enable composable solutions.

The Defense Modeling and Simulation Office (DMSO) is leading the effort to develop the required M&S Common Technical Framework (M&S CTF). The M&S CTF has three principal components:

- High Level Architecture (HLA)
- Conceptual Models of the Mission Space (CMMS), and
- Data Standards

as directed in DoD Directive 5000.59. Within the M&S Common Technical Framework and the associated authoritative representation objectives, the Data Engineering Technical Framework is

- the formal vehicle for promulgating and enforcing data standards, and
- a template for using data standards to create, manage, deliver, and employ data .

M&S activities will employ the DE-TF to provide composable data solutions which are:

- derived from authoritative sources,
- described using common semantics and syntax
- interchanged using standard formats,
- subject to rigorous quality checks,
- released to authorized consumers and,
- protected from unauthorized access or modification.

In particular, the data standards incorporated into the DE-TF (Figure 1) will provide

- Recognition of structure and content through common semantics and syntax, including:
    - standard naming conventions in a common lexicon,

  - entity-based and action-based data element dictionaries,
  - common taxonomies within identified application clusters,
  - layered architecture which separates implementation and problem domain semantics,
  - integration with existing standards from other (non-M&S) functional areas,
  - capture, matching, and mapping procedures and utilities,
- Realization of instance values within a data systems architecture, including
  - the Modeling and Simulation Resource Repository (MSRR) [1, 2] for consistent physical access and network connectivity,
  - families of interfaces (low-level formats, intermediate-level API, high-level GUI, etc.), and
  - hardware/software platform standards and constraints.
- Repeatability through data development processes which provide
  - a standard Data Production Sequence, and
  - a closed-loop Data Engineering Process.
- Reuse through data products, specifically:
  - development and designation of Authoritative Data Sources,
  - information exchange using Data Interchange Formats,
  - specification and employment of Data Quality (DQ) practices and
  - specification and enforcement of Data Security (DS) practices.
- Standards through DoD M&S Functional Data Administration (M&S FDAd).

DMSO is developing the DE-TF in conjunction with the JSIMS and JWARS M&S development programs, the Defense Information Systems Agency (DISA) with their associated Component and Functional Data Administrators, and the OSD PA&E Joint Data System. DMSO anticipates that a number of other Service and Component data programs will also make significant contributions to the DE-TF including: the Defense Intelligence Agency MIDB and MEPED, the Naval Warfare Tactical Database (NWTDB), and the Air Force MASTR database.

## 1.5. Specifications

DE-TF specifications are captioned:

- Minimum Requirement: mandatory specification considered necessary (but not necessarily sufficient) for data interoperability and re-use.
- Preferred Practice: best practices specification considered sufficient for data interoperability and re-use.
- Technology Extension: optional specification which in not considered mandatory for data interoperability and re-use but which is considered indicative of the technology adoption trend.

## 2. Fundamental Concepts

The DE-TF specification provided here will employ reserved words, first to define basic terms and concepts and then construct more general and complex terms and concepts from the basics:

**RESERVED WORD**

A specific term or concept which is defined and used to specify the Data Engineering Technical Framework. These terms will be typed in bold small caps.

Following the DoD M&S Master Plan [1], the definitions provided in the Glossary of M&S Terms [3], and the DoD Data Dictionary System (DDDS) [4] are included here as **RESERVED WORDS** by reference. Changes or extensions to these external definitions in this Data Engineering Technical Framework are italicized in the body of the definition.

### 2.1 Basic Definitions

This section develops the inter-related concepts of: data, model, information, representation, simulation, and resource in the context of modeling and simulation requirements. These terms are then employed to define fundamental data engineering concepts.

**DATA**

*Specification* of facts, *parameters*, *values*, concepts, or instructions in a formalized manner suitable for communications, interpretation, or processing by humans or by automatic means. This definition of **DATA** is a compatible modification[1] of the definitions in [3-4].

"Messages which resolve ambiguity are information. All other messages are noise." [5]. Therefore:

**INFORMATION**

**DATA** in context related to a specific purpose [6].

**MODEL**

A physical, mathematical, or otherwise logical *specification* of a system, entity, phenomenon, or process. This definition of **MODEL** is a compatible modification of the definitions in [3].

**REPRESENTATION**

The combination of a **MODEL**, process, or algorithm and the associated **DATA**, parameters, or values. Traditional implementations sharply separate algorithms and values. Contemporary object-oriented implementations joins **MODEL** and **DATA** as an object.

**SIMULATION**

The implementation of a **REPRESENTATION** over time. This definition is a compatible modification of the definition in [3]

**RESOURCE**

The entities and expendable which may be used by a process. Resources include **MODELS**, **DATA**, **REPRESENTATIONS**, **SIMULATIONS**, facilities, equipment, systems, software, source code, manpower, computer time, calendar time, funding, etc.

**DATA** is a critical enabling factor in the composable solutions strategy both as an end in itself and as a means to an end. As an example, consider the HLA Federation Development and Execution Process

[1] Replaced "representation" in [4-5] with "specification" to avoid circular definition of **REPRESENTATION**.

(FEDEP) depicted in Figure 2. The traditional focus of M&S data standards has been the start-exercise scenario instance DATA shown in the PRODUCTS block of Figure 2. This is DATA as an end in itself. Note that the every arrow on the diagram represents DATA interchange. Moreover, over one-half of the blocks on the diagram constitute RESOURCES which can converted to/from DATA for archive and interchange. Even within the TEST and EXECUTION blocks, the composable solutions strategy distributes SIMULATION functionality among the federates using HLA-compliant DATA interchange. This is DATA as a means to an end. The Data Engineering Technical Framework provides the development process, interoperability standards, and integration procedures required for DATA within the composable solutions strategy.

## 2.2 Representation

The cornerstone of the M&S Data Engineering Technical Framework is this: composable DATA solutions are feasible precisely when the associated REPRESENTATION is explicit. This is the essence of recognition and the jump off point for realization, extension to repeatability, and eventual reuse. In most circumstances, the choice of representation is a matter of focus. Two important components of this choice are

- the real world focus of the military activities of interest (the problem domain) and
- the synthetic world focus of the simulation application (the implementation domain).

### 2.2.1 Real World Focus

**ABSTRACTION**

> A mental facility that permits humans to view real world problems with varying degrees of detail depending on the current context of the problem [7]. ABSTRACTION is the real world equivalent of the synthetic world REPRESENTATION used in SIMULATION.

Real world military activities have a focus. While all physical and cognitive details of the real entities and their actual behaviors are present with perfect fidelity, not all details are important or are readily discernible in the focus of the real military operation. For example, consider an F/A-18 allocated to a deep penetration air interdiction mission. In the actual military operations, the details which are include or excluded, the granularity and aggregation of information provided to the real warfighter is very different if that warfighter is

- a general officer in the Unified Command,
- the wing commander in the JFACC air operations center,
- the flight leader in the strike package, or
- the pilot of the F/A-18.

That is, the real world executes real operations by introducing distinct ABSTRACTIONS which correspond exactly to the real world decomposition of tasks and allocation of RESOURCES. Note this introduction of ABSTRACTION is part to the problems space -- not the implementation domain.

This use of ABSTRACTION is an intrinsically human activity to reduce the full complexity of the real world to manageable proportions by filtering out unnecessary details [13]. Entities, actions, characteristics, and behaviors near the real world focus are ABSTRACTED to the real world actors with

- fine-grained decomposition's,
- extensive detail, and
- higher fidelity.

Entities and actions distant from the real world focus are ABSTRACTED with

- coarse-grained decomposition's,
- limited detail, and
- lower fidelity.

The objective of these ABSTRACTIONS employed in real activities is to provide DATA in context, i.e. INFORMATION, to support decisions by rejecting noise. In real world or problem domain, the DATA is almost always explicitly provided as INFORMATION; whereas, the underlying MODEL which completes the ABSTRACTION usually is implicit. Under the M&S Common Technical Framework, this understanding of the real world is captured and maintained as Conceptual Models of the Mission Space (CMMS) [8].

Minimum Requirement:

> DATA created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be traceable to an appropriate REPRESENTATION of the corresponding problem domain ABSTRACTION registered in CMMS.

### 2.2.2 Simulation Focus

Just as real operations have a focus, every simulation has a focus. The simulation focus is derived from the real world focus and the simulation objectives as follows:

- Obtain REPRESENTATIONS of the real world focus of the entities, actions, tasks, and interactions of interest from CMMS.
- Extend the scope and context of the real world focus to include notional entities/actions, hypothetical situations, and to-be conditions -- again in the form of CMMS REPRESENTATIONS.

The simulation objectives are then imposed as constraints on the extended real world focus to complete the simulation focus. These constraints imposed by the simulations are often called the Conceptual Model of the User Space (CMUS) [9]. Typical constraints on the simulation focus include:

- the range of anticipated Essential Elements of Analysis (EEA's) or Measures of Effectiveness (MOE's) in analysis applications,
- the training audience and readiness objectives (e.g. the WarSim Task Requirements Analysis Process or TRAP),
- real-time, faster than real-time, or as fast as possible computational requirements, or perhaps
- the anticipated hardware/software platforms with associate processing limits.

Just as in the real world focus, synthetic entities, actions, characteristics, and behaviors near the simulation focus are REPRESENTED with

- fine-grained decomposition's,
- extensive detail, and
- higher fidelity.

And synthetic entities and actions distant from the simulation focus are REPRESENTED with

- coarse-grained decomposition's,
- limited detail, and
- lower fidelity.

The correlation between the real world focus, the simulation focus, and the specific REPRESENTATION chosen is critical. For an identified simulation focus, DATA is created to complete the synthetic REPRESENTATIONS of these real world entities and actions for use in a simulation. Note that REPRESENTATIONS are plural here. For any specific entity or action, there is usually

- more than one REPRESENTATION

or within a particular REPRESENTATION

- more than one MODEL and/or
- more than one set of DATA elements

that provide an appropriate description of that entity or action depending upon the real world context and the simulation focus. That is, for any specific entity or action, there are families of distinct but related REPRESENTATIONS, MODELS, and/or DATA. Whether a verified and validated REPRESENTATION is INFORMATION or noise depends upon the end-use.

Minimum Requirement:

> DATA created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be traceable to an appropriate REPRESENTATION of the implementation domain ABSTRACTION registered in a CMUS.

## 2.3 Primary Components

There are five primary components of the M&S Data Engineering Technical Framework:

- Common Semantics and Syntax
- Data Systems Architecture
- Data Processes
- Data Products
- M&S Functional Data Administration

### 2.3.1 Common Semantics and Syntax

A fundamental objective of data standards is to provide simulation developers and end-users with timely and cost-effective access to accurate DATA which are created, authenticated, and maintained by others. DATA recognition is the first requirement. No DATA set, however valuable, will be consider from inclusion in a composable solution if that data's suitability/appropriateness for the solution is not recognizable to the simulation developer or end-user. In many cases, the official language used by subject matter experts in distinct warfare or the well established nomenclature in a specific technologies is a barrier to this direct use and re-use of DATA. While correct and legitimate within its own domain, the official semantics and syntax in one warfare area or technical discipline often is in direct conflict with the formal language in another domain. Even at a basic vocabulary level, there are cases where identical words are used to mean very different things, and there are cases where different words are used to mean the same thing. To make effective use of Data Standards, simulation developers require REPRESENTATIONS and their associated MODELS and DATA that map domain specific descriptions to a common semantics and syntax.

**SYNTAX**

The symbols and structures which may be used in a REPRESENTATION and the ways that those symbols may be arranged within the allowed structures.

**SEMANTICS**

The content or meaning embodied in the symbols and symbol arrangements defined in a SYNTAX.

**COMMON SEMANTICS AND SYNTAX**

An implementation-independent logical specification of REPRESENTATION structure and content within a specified scope and context.

**FORMAT**

a set of semantic and syntactic conventions that define the physical implementation of DATA.

The central objective of COMMON SEMANTICS AND SYNTAX is RESOURCE recognition. For DATA RESOURCES, CSS is usually defined as an IDEF1X logical DATA model [10-12] with associated DATA element dictionary. Within the composable solutions strategy, CSS provides

- standard naming conventions in a common lexicon,
- entity-based and action-based data element dictionaries,
- common taxonomies within identified application clusters,
- layered architecture which separates implementation and problem domain semantics,
- integration with existing standards from other (non-M&S) functional areas, and
- capture, matching, and mapping procedures and utilities,

which enable simulation developers and end-users to readily recognize existing components as candidates for implementing their requirements.

The F/A-18 REPRESENTATION example cited in Section 2.2 is a special case of a more general observation [13] that ABSTRACTION

- in the form of a hierarchical chain of command and control is central to the planning and execution of military operations, and

- in the form of a hierarchical chain of components and networks is central to the processing characteristics and performance of military systems.

That is, real organizations and systems employ layered architectures to accommodate and implement the required hierarchies of abstraction. Therefore, CSS recognizes distinct but related families of **REPRESENTATIONS** in a layered architecture which explicitly mimics the real world usage of hierarchical **ABSTRACTION.**

Recall that the primary purpose of **COMMON SEMANTICS AND SYNTAX** is provide **DATA** recognition by making the **REPRESENTATION** explicit. Therefore the first step in developing CSS is to identify the key organizing principles (or primary dimensions) which describe the military activities of interest. As an example, consider the JWARS and JSIMS mission space. As illustrated in Figure 3, there are (at least) three primary organizing principles or dimensions:

- level of war,
- phase of campaign, and
- allegiance of forces

required to describe the JWARS and JSIMS mission space. While there certainly are more organizing principles within the JWARS/JSIMS domain (from example, analysis versus training), the number of primary dimension which can be accommodated is finite and usually less than seven [14]. Within any specific cell in Figure 3, CSS provides standards terms of reference, naming conventions, structures, and taxonomies based on the focus -- both real world and simulation related -- of the activities and entities in that cell. Between cells mapping and matching interfaces will be required -- either because the representations of the same real world entity/action are distinct or because the naming and nomenclature are distinct.

The organizing principles defined in Table 1 are of particular importance within the M&S Data Engineering Technical Framework. The Universal Joint Task List (UJTL) [15] defines military operations in terms of the four hierarchical layers (or levels of war) shown in the left most column of Table 1 as follows:

**STRATEGIC LEVEL**

The level at which national command authorities and combined operational commands determine the security objectives and warfare guidance with associated allocation of **RESOURCES.** With these objectives, guidance's, and **RESOURCES, STRATEGIC LEVEL** activities establish missions, national and multi-national objectives, sequence initiatives, define limits , and assess risks for the use of military and other instruments of national power. At the **STRATEGIC LEVEL**, the activities lead to the development of global and theater war plans and the provision of military forces and capabilities.

**OPERATIONAL LEVEL**

The level at which combined operational commands, joint and Service specific task forces plan, conduct, and sustain **STRATEGIC LEVEL** objectives within geo-spatial theaters of activity. These activities link the **STRATEGIC LEVEL** and the **TACTICAL LEVEL** by establishing objectives, sequencing events initiating actions, and applying **RESOURCES** at the appropriate **OPERATIONAL LEVEL.**

**TACTICAL LEVEL**

The level at which joint and Service specific task forces, individual military units, and multi-role platforms plan and execute the ordered arrangement and maneuver of combat elements in space and time relative to own and adversary forces to achieve combat objectives.

The **STRATEGIC LEVEL** is usually sub-divided into **STRATEGIC-NATIONAL** and **STRATEGIC-THEATER** levels as shown in the table. Within each UJTL level of war, the items to be **REPRESENTED** are organized according to:

**TASK REPRESENTATION**

The **REPRESENTATION** of actions to be executed and processes to be performed within a mission.

**PHYSICAL REPRESENTATION**

The **REPRESENTATION** of engineering, physics, chemistry, biology, or psychology principles to determine material characteristics and performance or to establish human cognitive and psychological factors.

**WARFIGHTER REPRESENTATION**

The **REPRESENTATION** of individual persons employing physical **RESOURCES** (platforms, systems, sensors, munitions, communications, etc.) to execute a task.

The DoD Instruction 5000.59 defines these types of simulations:

**LIVE SIMULATION**

Real **WARFIGHTERS** interacting with real systems in a real environment

**VIRTUAL SIMULATION**

Real **WARFIGHTERS** interacting with synthetic systems in a synthetic environment

**CONSTRUCTIVE SIMULATION**

Synthetic **WARFIGHTERS** interacting with synthetic systems in a synthetic environment

Cells in the same row of Table 1 share common actions and entities at the same level of warfare. Mapping and matching is required to substitute synthetic representation for real items when moving horizontally from real operations on the left to completely synthetic operations on the right. Cells in the same column share the same mixture of real and synthetic. Aggregation/de-aggregation interfaces are required to move vertically between levels of war.

Organization of **REPRESENTATIONS** according to

- UJTL level of warfare,
- degree of synthetic **REPRESENTATION**, and
- the relative focus among action, entity, or actor

are the foundation of **COMMON SEMANTICS AND SYNTAX** within the M&S Data Engineering Technical Framework. Therefore:

Minimum Requirement: **DATA** created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be described using **COMMON SEMANTICS AND SYNTAX**, including but not limited to:

A taxonomy which identifies the key organizing principles and primary describing dimensions of the **REPRESENTATION** which the **DATA** completes. This taxonomy shall include but is not limited to the organizing principles defined in Table 1.

DATA element dictionary which complies with the DoD Data Dictionary System [4] structure and content specifications.

A DATA model which defines the relationships between the elements in the DATA dictionary within the taxonomy provided and which complies with the DoD Data Model [16] structure and content specifics.

Preferred Practice:

The required CSS DATA model and associated DATA elements should be constructed in accordance with DoD 5000.59-M-1 [17].

Technology Extension:

Employ the Data Analysis and Reconciliation Tool (DART) [18] to define entity-based DATA elements.

Employ the CMMS Verb Dictionary [19] to define action-based DATA elements

Employ the Comprehensive Utilities for Data Administration (CUDA) [20] procedure for reconciling and deconflicting DATA elements and DATA models.

### 2.3.2 Data Systems Architecture

RESOURCE realization as the central objective of DATA systems architecture within DE-TF. Systems architecture:

- defines the connection, location, and identification of key nodes, networks, and DBMS platforms and specifies the required system and component performance parameters, and
- is constructed to satisfy the operational architecture requirements in via products and standards defined in DATA Products.

The DATA systems architecture addresses system implementation requirements at two levels:

- the DATA development processes for creating, registering, maintaining, interchanging, and releasing of data prior to simulation execution, and
- the DATA employment processes for runtime selection and manipulation of data for employment or transmission during simulation execution.

The DATA development processes will be defined in Section 2.4.3 below. Discussion of the DATA employment processes is beyond the scope of DE-TF version 0.2.

DATA systems architecture describes how multiple DATA systems within a subject area link and interoperate. While external specifications are preferred, internal construction or operations of specific systems may be described where the internal details affect interoperability and reuse. In particular DATA systems architecture:

- describes the components and structure of the physical process which automate or enable DATA operations
- identifies system interfaces and defines the connectivity between systems,
- defines system constraints and bounds of system performance behavior,
- describes technology dependence is specific systems implementations, and
- shows systems interconnectivity from consumer through the repository to the producer (and authoritative data source) via the quality examiner, security officer, and requirements manager.

In DE-TF version 0.2, the data systems architecture specifies a minimal information systems infrastructure which is necessary (but not sufficient) for DATA realizations, including

- the Modeling and Simulation Resource Repository (MSRR) [1, 3] for consistent physical access and network connectivity,
- a families of DATA interfaces, and
- DISA Shared Data Environment (SHADE) [22] compatibility.

The MSRR is a collection of M&S registered RESOURCES and RESOURCE references, logically organized by information categories, and physically implemented using a distributed system of RESOURCE servers connected through the World Wide Web (WWW). The MSRR provides an additional layer of services above the WWW that includes registration of RESOURCES, users, and nodes; description and quality tagging of RESOURCES; security and releasability; and specialized search capabilities. MSRR provides a distributed repository for

approved M&S RESOURCES. The primary objectives of the MSRR are to provide members of the M&S community with a facility to electronically:

- Register users, nodes, and RESOURCES with the MSRR Registrar.
- Store location and descriptive information about M&S RESOURCES.
- Protect sensitive but unclassified DATA.
- Store selected M&S RESOURCES.
- Search for RESOURCES via categories using search engines and database queries on the master registration database.
- Access authorized descriptive information about M&S RESOURCES.
- Navigate among the MSRR nodes and review RESOURCES on those nodes while retaining an MSRR identity.
- Access authorized M&S RESOURCES stored on the MSRR or on nodes external to the MSRR.
- Request M&S RESOURCES from RESOURCE providers.

Minimum Requirement:

> DATA systems implementations which support a DATA development processes shall be MSRR compliant.

The conversion and integration of data requires formal format standards and interfaces definitions. The DATA system architecture defines a hierarchical family of Data Interchange Format (DIF) definitions, interfaces, tools, and utilities including

- low level, file format or DBMS schema interface definitions in the form of Interface Description Language (IDL) [23], Structured Query Language (SQL) [24], and/or Backus Naur Form (BNF) [25],
- intermediate level, simulation developer Application Programming Interfaces (API's) in the form of Common Object Services Specifications (COSS) [26] and/or native programming language calls, and
- high level, simulation end-user Graphical User Interface (GUI) capability in the form of Common Object Facilities [27] and/or native windowing schema's.

Minimum Requirement::

> DATA systems implementations which support a DATA development processes shall provide a low level format or schema interface definition using at least one of the following forms: OMG CORBA IDL, ANSI/ISO SQL, or BNF.

Preferred Practice: DATA systems implementations which support a DATA development process should:

> provide an intermediate, simulation developer API, either as an OMG COSS or as a set of native high-level programming language calls, and

provide high level, simulation end-user Graphical User Interface (GUI) capability in the form of an OMG Common Object Facilities or a native windowing schema.

The DISA Shared Data Environment (SHADE) is an emerging DoD systems architecture standard for data. M&S Data Standard Architecture compatibility and interoperability with the SHADE beyond the scope of DE-TF version 0.2

### 2.3.3 Data Processes

DE-TF DATA process are decomposed into two primary activities -- those to develop required DATA prior to simulation execution and those to actually employ DATA during simulation execution:

DATA Development Processes
: Descriptions of the tasks, operational elements, and information flows required for creating, registering, maintaining, interchanging, and releasing M&S DATA prior to simulation execution.

DATA Employment Processes
: Descriptions of the tasks, operational elements, and information flows required for runtime selection and manipulation of M&S DATA for employment or transmission during simulation.

This section specifies the DE-TF DATA development processes. Discussion of the DATA employment processes is beyond the scope of version 0.2 of the M&S Data Engineering Technical Framework provided here.

REPRESENTATION implementation and DATA development are concurrent, spiral development activities [28, 29] which execute iteratively until the simulation life-cycle is complete. To meet these requirements, the DATA development processes defines two distinct (but compatible) views into the underlying DATA life-cycle:

- the closed-loop, repository-centric DATA ENGINEERING PROCESS (Figure 4)
- the developer-centric DATA PRODUCTION SEQUENCE (Figure 5) and

within the overall simulation development and employment life-cycle. The central objective of the DATA development processes are RESOURCE implementation repeatability. Within this objective:

- The DATA ENGINEERING PROCESS focuses on an iterative, spiral development life-cycle for enterprise use and re-use of RESOURCES.
- The DATA PRODUCTION SEQUENCE focuses on a once-through waterfall development process for delivering a specific version of a RESOURCE by a particular developer within the larger DATA Engineering Process spiral.

#### 2.4.3.1 Operational Elements

There are five primary operational elements or functional roles performed by simulation developers, end-users, and problem domain experts shown as blocks within the DATA ENGINEERING PROCESS diagram depicted in Figure 4:

CONSUMER
: The combination of PERSON and ORGANIZATION which executes the ROLE of RESOURCE employment. PERSON, ORGANIZATION, and ROLE are defined in [5, 29].

**SPONSOR**

The combination of a **PERSON**, **ORGANIZATION**, and **ROLE** which constitute the actor which has been assigned a.) the command responsibility for specific content, structure, quality, process, or ownership of a **RESOURCE** and/or b.) the management authority over the **RESOURCES** required to execute command responsibilities.

**PRODUCER**

The combination of **PERSON**, **ORGANIZATION**, and **ROLE** which constitute the actor who, because of either mission or subject matter expertise, actually creates, manufactures, or constructs specific **RESOURCES**.

**ADMINISTRATOR**

The combination of **PERSON** and **ORGANIZATION** which executes the **ROLE** of **RESOURCE** repository management.

**EXAMINER**

The combination of a **PERSON**, **ORGANIZATION**, and **ROLE** which constitute the actor that actually inspects, tests, and evaluates specific **REPRESENTATION** content, structure, or process for the purpose of verification, validation, and certification or accreditation.

### 2.4.3.2 Information Exchange Requirements

There are seven primary information exchange requirements (or interactions) between the five operational elements (or functional roles) shown as arrows within the **DATA** Engineering Process diagram shown in Figure 4:

**SPECIFY**

The explicit description of requirements for a **RESOURCE**. **SPECIFY** provides the black-box definition of external characteristics, performance, capabilities, and interfaces required of a **RESOURCE** in the form of CMMS and CMUS **REPRESENTATIONS** and, for **DATA RESOURCES DATA** element dictionaries and (IDEF1X) **DATA** models defining the logical content and physical constraints. The **CONSUMER** has the lead **ROLE** to propose and deliver **RESOURCE SPECIFICATIONS**. The **SPONSOR** has the response **ROLE** to identify, review, and concur with **RESOURCE SPECIFICATIONS**.

**ENDORSE**

The formal delegation of **SPONSOR** authority to implement an **APPROVED RESOURCE** by expending **RESOURCES ALLOCATED** for that purpose. The **SPONSOR** has the lead **ROLE** to propose and deliver an **ENDORSEMENT**. The **PRODUCER** has the response **ROLE** to identify, review, and concur with an **ENDORSEMENT**.

**REGISTER**

The formal delivery of a **RESOURCE** for actual inclusion in a repository, especially MSRR, including source, format, and content checking with deficiency correction as appropriate. The **PRODUCER** has the lead **ROLE** to propose and deliver a **REGISTRATION** subject to **SPONSOR APPROVAL**. The **ADMINISTRATOR** has the response **ROLE** to identify, review, and concur with a **REGISTRATION** subject to **SPONSOR ALLOCATION**.

**RELEASE**

The formal permission to delivery a **RESOURCE** for **CONSUMER** activities, especially via MSRR, including the provision of security services, access control, user identification for use and examination of the **RESOURCE**. The **ADMINISTRATOR** has the lead **ROLE** to enforce release policy subject to sponsor approval and the response **ROLE** to deliver **RELEASED RESOURCES** subject to **SPONSOR ALLOCATION**. The **CONSUMER** has the lead **ROLE** to propose and justify **RESOURCE RELEASE** and the response **ROLE** to receive **RELEASED RESOURCES**.

REQUEST

The identification of the need for a formal RESOURCE EXAMINATION. The CONSUMER has the lead ROLE to identify the RESOURCE and to propose the EXAMINATION. The EXAMINER has the response ROLE to review and concur with the proposed RESOURCE EXAMINATION subject to SPONSOR AUTHORIZATION.

AUTHORIZE

The combination of APPROVAL AND ALLOCATION which constitute formal sanction of the requirement to EXAMINE a resource, of the designation of a RESOURCE as AUTHORITATIVE, or of the permission to RELEASE a RESOURCE. . The SPONSOR has the lead ROLE provide AUTHORIZATION. The CONSUMER, PRODUCER, ADMINISTRATOR, and EXAMINER have the response ROLE to review and concur with proposed AUTHORIZATIONS.

SUBMIT

The formal delivery of a resource for EXAMINATION. The PRODUCER has the lead ROLE to assemble, format, package, and deliver the RESOURCE and supporting meta-DATA for use by the EXAMINER. The EXAMINER and CONSUMER has the response ROLE to identify, review, and concur with the RESOURCE SUBMISSION subject to SPONSOR AUTHORIZATION.

### 2.4.3.3 Activities

Within the five primary operational elements or functional ROLES performed by simulation developers, end-users, and problem domain experts, there are a number of activities conducted primarily or exclusively by that functional ROLE. These activities are shown as a list of actions within the operational element blocks within the DATA Engineering Process diagram shown in Figure 4:

The CONSUMER ROLE executes these four DATA Engineering Process activities:

LOCATE

The use of on-line browsing tools, automated searches, and retrieval queries to identify RESOURCES of interest. COMMON SEMANTICS AND SYNTAX is applied to construct searches and to recognize RESOURCES.

ACCESS

The use of RESOURCE retrieval services to obtain located RESOURCES. For DATA RESOURCES, DATA INTERCHANGE FORMATS are employed via application programming interfaces and/or graphical user interface (GUI) services to gather, FORMAT, package, and deliver DATA to the CONSUMER.

EVALUATE

CONSUMER actions to determine that a particular RESOURCE does or does not satisfies specific CONSUMER requirements.

EMPLOY

CONSUMER usage of a particular RESOURCE to satisfy specific end-use requirements.

The SPONSOR ROLE executes these two DATA Engineering Process activities:

APPROVE

The command decision and official sanction with respect to a RESOURCE that a requirement is justified, a REGISTER or RELEASE is appropriate, an EXAMINATION is satisfactory, or a DATA SOURCE is AUTHORITATIVE.

**ALLOCATE**

The programmatic authority and official sanction to expend **RESOURCES** to fulfill a requirement, to perform a **REGISTER** or conduct a **RELEASE**, or to conduct an **EXAMINATION**.

The **PRODUCER ROLE** executes these four **DATA** engineering process activities:

**DESIGN**

The deliberate purposive planning by which the nature and arrangement of elements which constitute a **RESOURCE** are described and a scheme for implementing these elements is devised. **DESIGN** provides the clear-box definition of the internal elements of a **RESOURCE**.

**CREATE**

The actual construction of a **RESOURCE**.

**CONVERT**

Transformation of a **REGISTERED RESOURCE** from its native form into **DATA** in a standard form with **COMMON SEMANTIC AND SYNTACTIC** elements for archive and interchange.

**INTEGRATE**

The act of combining, normalizing, mapping, matching, indexing, and in general migrating **REGISTERED DATA** in standard form to a higher level of syntatic maturity and semantic enforcement within a common repository.

The **ADMINISTRATOR ROLE** executes these four **DATA** engineering process activities:

**CATALOG**

The provision of a complete enumeration of **REGISTERED RESOUCES** arranged systematically within an appropriate taxomony which provides meta-**DATA** and descriptive details to support **CONSUMER LOCATE** and **ADMINISTRATOR STORE, CONFIGURE,** and **PURGE** activities.

**STORE**

The provision of resource persistence and recovery. For **DATA RESOURCES,** the provision of persistent file server and DBMS **RESOURCES**.

**CONFIGURE**

The provision of **RESOURCE** configuration management, version control, and change traceability.

**PURGE**

The removal and retirement of (previously) persistence **RESOURCES**.

### 2.3.3.4 Data Production Sequence

While the **DATA ENGINEERING PROCESS** provides a view of the overall use and reuse of **DATA** via a common (likely distributed) repository, the **DATA PRODUCTION SEQUENCE** (Figure 5) focuses on the development of a specific set of **DATA** instances:

- by a **PRODUCER**,
- to complete an explicit **REPRESENTATION**,
- to meet an **ENDORSED** set of requirements,
- as specified by a **CONSUMER**.

The DATA PRODUCTION SEQUENCE is a refinement and elucidation of the DESIGN and CREATE activities. Within this sequence, the PRODUCER has the lead ROLE to propose and conduct the activities and initiate the information exchanges required to ultimately construct the required DATA. The CONSUMER, ADMINISTRATOR, EXAMINER and SPONSOR have the response ROLE to identify and provide the AUTHORIZED input RESOURCES for the CREATE-related activities and to review and concur with DESIGN-related activities.

This sequence is composed of four primary activities conducted by the PRODUCER operational element, with appropriate assistance from the other operational elements. These activities are shown as a sequence of boxes within the DATA Engineering Process diagram shown in Figure 5:

DEVELOP FOCUSED CONTEXT

SPECIFY concrete operational conditions using CMMS REPRESENTATIONS, establish end-user priorities and constraints using CMUS REPRESENTATIONS, and establish output RESOURCE requirements using ENDORSED SPECIFICATIONS.

GATHER INFORMATION

Establish the preliminary design by conducting coordinated RESOURCE repository searches and site-visits to subject matter experts to LOCATE, EVALUATE, and ultimately obtain RELEASE of required input RESOURCES within the FOCUSED CONTEXT.

FORMALIZE INPUT RESOURCES

Complete the detailed DESIGN the required resource by organizing the input RESOURCES, using COMMON SEMANTICS AND SYNTAX and DATA INTERCHANGE FORMATS, where appropriate, into standard forms for PRODUCTION use.

CONSTRUCT RESOURCE

EMPLOY the FORMALIZED INPUT RESOURCES to PRODUCE the required output RESOURCES.

The arrows between the activity blocks in Figure 5 represent information exchange requirements, likely via MSRR, as define in Section 2.4.3.2 above.

Minimum Requirement:

DATA CREATED, REGISTERED, maintained and RELEASED under the M&S Data Engineering Technical Framework shall be PRODUCED in accordance with the DATA PRODUCTION SEQUENCE.

DATA CREATED and EMPLOYED under the M&S Data Engineering Technical Framework shall be SPONSORED, PRODUCED, EXAMINED, ADMINISTERED, and CONSUMED in accordance with the DATA ENGINEERING PROCESS.

### 2.4.4 Data Products Technical Architecture

The central DATA products objective is to enable the composable solutions strategy by defining reusable, shrink-wrapped RESOURCES. For DATA RESOURCES, DE-TF defines five key DATA products

- authoritative data sources
- authorized data consumers
- data interchange formats
- data quality products and procedures

- data security products and procedures

### 2.3.4.1 Authoritative Data Sources

This section describes the REPRESENTATION requirements which ensure that the accuracy and authenticity of any particular DATA is specified in sufficient detail for a simulation developer or end-user to recognize the suitability of that DATA for that simulation developer's or end-user's specific requirements.

**PRODUCTION PEDIGREE**

The comprehensive audit trail which describes the specific methods and procedures actually employed by the PRODUCER to create, derive, and construct a particular DATA instance for specified end-use. This PEDIGREE provides DATA SOURCE traceability for constituent DATA instances which were incorporated into or employed to produce the particular DATA instance in question.

**DATA SOURCE (DS)**

The combination of SPONSOR, PRODUCER, DATA, and PRODUCTION PEDIGREE which provide a DATA instance. The PRODUCER creates the actual DATA instance by direction of the SPONSOR and records these activities in the PEDIGREE. This definition of DATA SOURCE is a compatible extension of the definitions in [3-4].

**VV&C PEDIGREE**

The comprehensive audit trail which records the formal verification, validation, and accreditation activities actually performed on a particular DATA SOURCE by the EXAMINER. This PEDIGREE also provides traceability for input DATA instances or MODELS which a.) were employed to produce the actual DATA instances provided in the DATA SOURCE in question but which b.) were not delivered along with these actual DATA instances being EXAMINED.

**AUTHORITATIVE DATA SOURCE (ADS)**

The combination of SPONSOR, EXAMINER, DATA SOURCE, and VV&C PEDIGREE which provide one or more DATA instances have verified, validated, certified/accredited in accordance with appropriate DoD or Service VV&C procedure. The EXAMINER analyzes that actual DATA instance provide by the DATA SOURCE under direction of the SPONSOR and records these activities in the VV&C PEDIGREE. This definition of AUTHORITATIVE DATA SOURCE(ADS) is a compatible extension of the definitions in [3-4].

Minimum Requirement:

All DATA shall be REGISTERED by an AUTHORITATIVE DATA SOURCE which have been APPROVED by an appropriate Joint, Service, or Agency SPONSOR.

For example, in the military operation mission space, the actual warfighter in hostile, live-fire combat operations is the original DATA SOURCE. However, simulations based on such a DATA SOURCE are of minimal value in the absence of verification, validation, and eventually accreditation. Doctrine is a disciplined attempt to learn for these warfighter experiences. Just so, the requirement that all DATA be REGISTERED by an AUTHORITATIVE DATA SOURCE is an attempt to introduce that same discipline into simulations. This ADS framework provides the rigorous DATA SOURCE traceability and configuration management which is required to support VV&C by competent authority.

Preferred Practice:

To support concurrent work-in-progress by DATA SOURCE, VV&C EXAMINER, and simulation developers, DATA from a SPONSOR APPROVED DATA SOURCE may be REGISTERED, CONVERTED, and INTEGRATED in

parallel with EXAMINER activities to provide the required VV&C for AUTHORITATIVE DATA SOURCE approval.

### 2.3.4.1 Authorized Data Consumers

This section describes the requirements which control the RELEASABILITY of any particular DATA to a specific simulation developer.

**CLEARANCE**

The AUTHORIZATION that a specific CONSUMER is legally eligible to be entrusted with classified, proprietary, or otherwise sensitive DATA instance.

**ACCESS**

The AUTHORIZATION that a specific combination of a CONSUMER with a particular CLEARANCE under the authority of an identified SPONSOR has an appropriate need-to-know for a specific classified, proprietary, or otherwise sensitive DATA instance.

**SECURITY PEDIGREE**

The comprehensive audit trail which records the specific methods and procedures actually employed by the CONSUMER under authority of the SPONSOR to ensure that any specific DATA instance has been properly protected

**DATA CONSUMER (DC)**

The combination of SPONSOR, CONSUMER, CLEARANCE, ACCESS, and SECURITY PEDIGREE which requests permission to LOCATE, EXTRACT, or EVALUATE a specific DATA instance. The CONSUMER requests and eventually receives the actual DATA instance by direction of the SPONSOR and records these activities in the SECURITY PEDIGREE.

**RELEASE PEDIGREE**

he comprehensive audit trail which records the specific methods and procedures actually employed by the ADMINISTRATOR under authority of the AUTHORITATIVE DATA SOURCE (**ADS**) to RELEASE any specific DATA instance to a DATA CONSUMER.

**AUTHORIZED DATA CONSUMER**

The combination of DATA CONSUMER, AUTHORITATIVE DATA SOURCE and RELEASE PEDIGREE certifies the RELEASE of one or more DATA instances from the AUTHORITATIVE DATA SOURCE to the DATA CONSUMER. The ADMINISTRATOR records these activities in the RELEASE PEDIGREE. This definition of AUTHORIZED DATA CONSUMER (ADC) is a compatible extension of the
definitions in [3-4].

Minimum Requirement:

> Each CONSUMER shall be an AUTHORIZED DATA CONSUMER. DATA shall not be RELEASED to any CONSUMER who is not an AUTHORIZED DATA CONSUMER.

#### 2.3.4.3 Data Interchange Formats

**[TBD]**

#### 2.3.4.4 Data Quality Products and Procedures

**[TBD]**

#### 2.3.4.5 Data Security Products and Procedures

**[TBD]**

### 2.3.5 Functional Data Administration

**[TBD]**

## 3. Detailed Definition of M&S DE-TF Products and Processes

**[TBD]**

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## 5. Figures

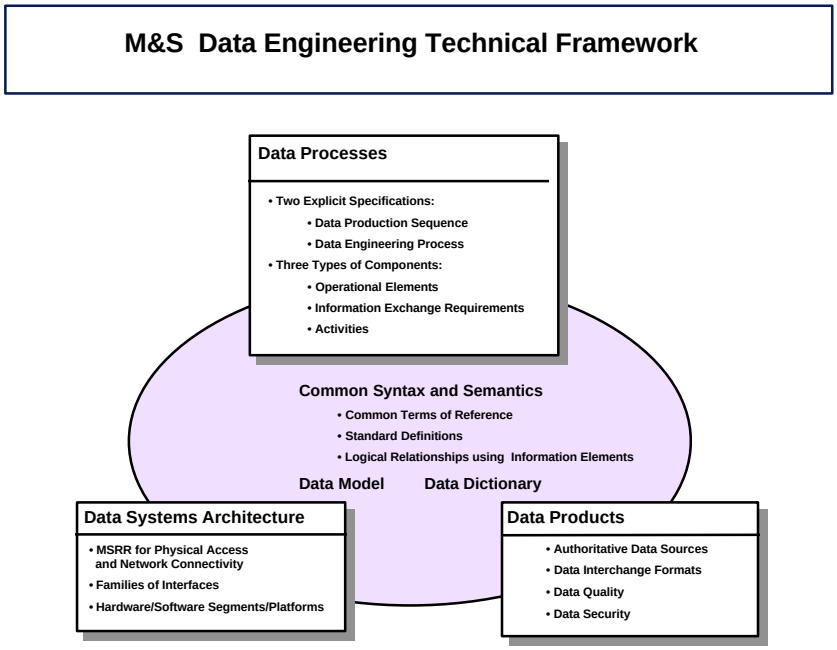


Figure 1

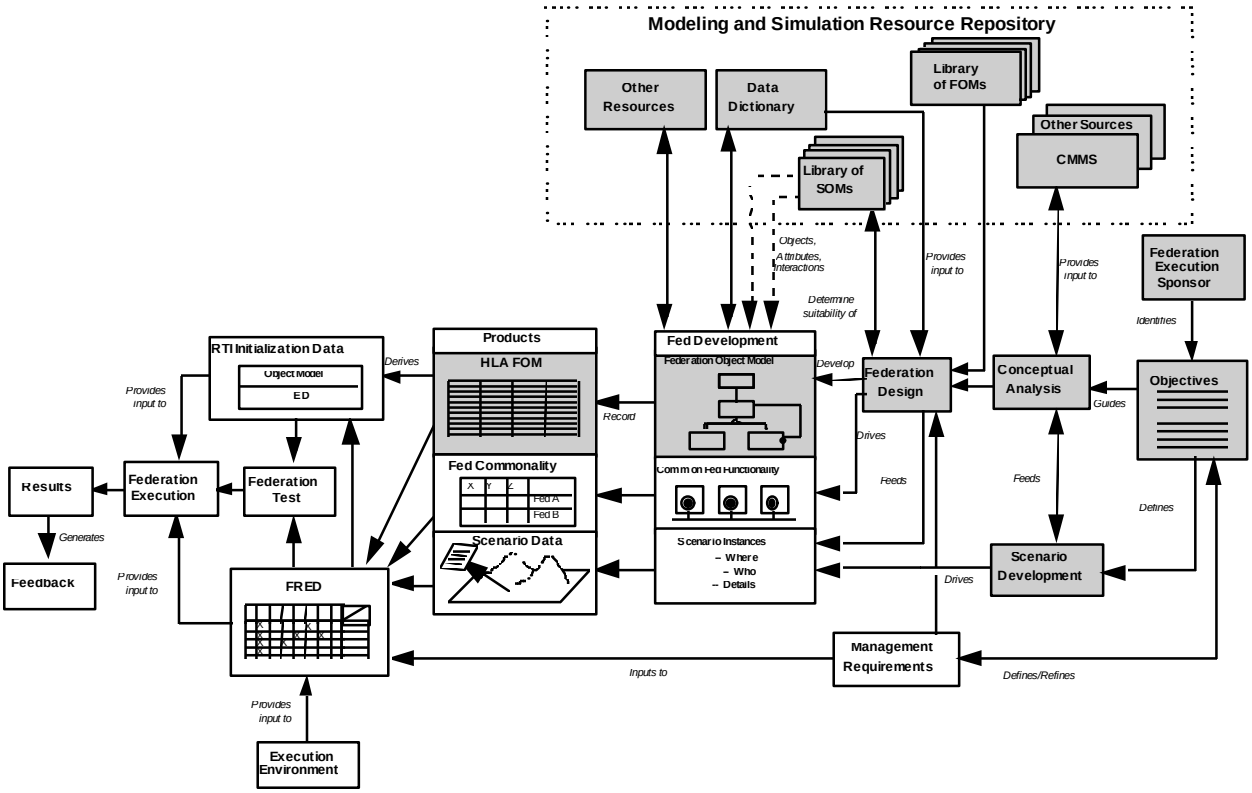


**Figure 2-1. Federation Development and Execution Process Model**


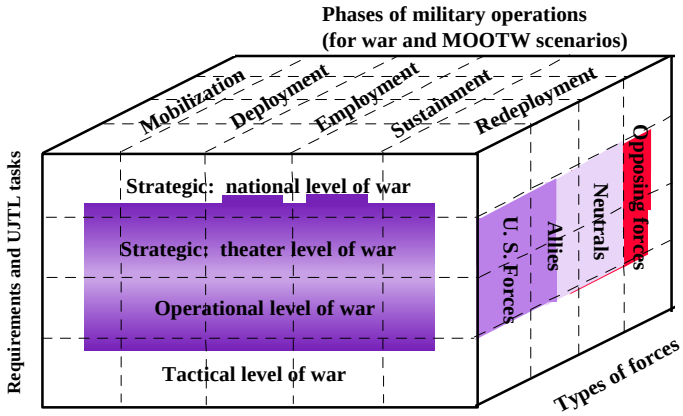


Figure 3

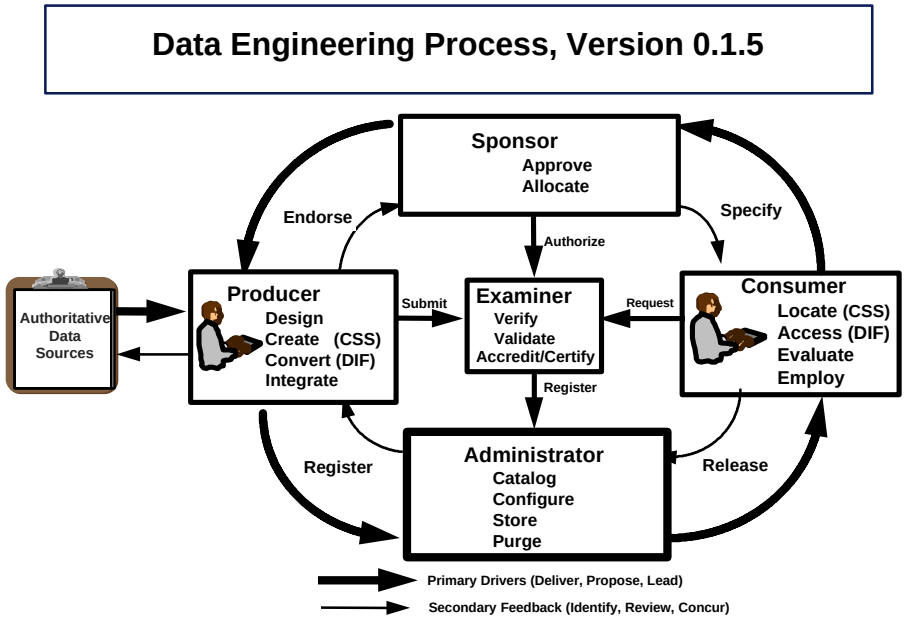


Figure 4

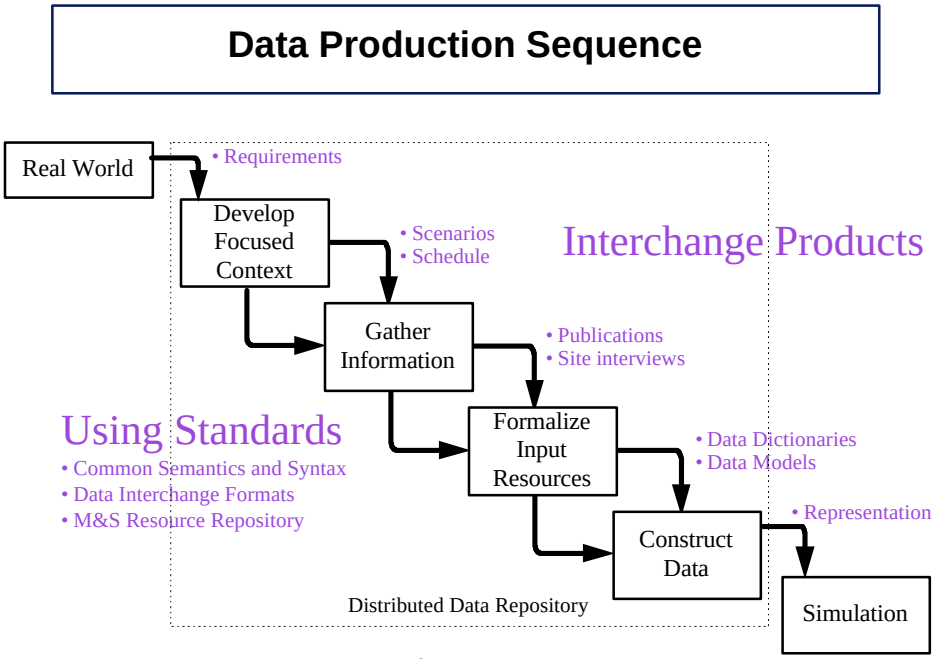


Figure 5

## 6. Tables

**Table 1**

| UJTL LEVEL OF WAR | LIVE SIMULATION | VIRTUAL SIMULATION | CONSTRUCTIVE SIMULATION |
|---|---|---|---|
| **STRATEGIC NATIONAL** | | | |
| **TASK** | synthetic | synthetic | synthetic |
| **PHYSICAL** | real | synthetic | synthetic |
| **WARFIGHTER** | real | real | synthetic |
| **STRATEGIC THEATER** | | | |
| **TASK** | synthetic | synthetic | synthetic |
| **PHYSICAL** | real | synthetic | synthetic |
| **WARFIGHTER** | real | real | synthetic |
| **OPERATIONAL** | | | |
| **TASK** | synthetic | synthetic | synthetic |
| **PHYSICAL** | real | synthetic | synthetic |
| **WARFIGHTER** | real | real | synthetic |
| **TACTICAL** | | | |
| **TASK** | synthetic | synthetic | synthetic |
| **PHYSICAL** | real | synthetic | synthetic |
| **WARFIGHTER** | real | real | synthetic |

## 7. Specifications Compendium

### 7.1. Minimum Requirements:

1 DATA created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be traceable to an appropriate REPRESENTATION of the corresponding problem domain ABSTRACTION registered in CMMS.

2 DATA created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be traceable to an appropriate REPRESENTATION of the implementation domain ABSTRACTION registered in a CMUS.

3 DATA created, registered, maintained and released under the M&S Data Engineering Technical Framework shall be described using COMMON SEMANTICS AND SYNTAX, including but not limited to:

3.1 A taxonomy which identifies the key organizing principles and primary describing dimensions of the REPRESENTATION which the DATA completes. This taxonomy shall include but is not limited to the organizing principles defined in Table 2.

3.2 DATA element dictionary which complies with the DoD Data Dictionary System [5] structure and content specifications.

3.3 A DATA model which defines the relationships between the elements in the DATA dictionary within the taxonomy provided and which complies with the DoD Data Model [17] structure and content specifics.

4 DATA systems implementations which support a DATA development process shall be MSRR compliant.

5 DATA systems implementations which support a DATA development process shall provide a low level format or schema interface definition using at least one of the following forms: OMG CORBA IDL, ANSI/ISO SQL, or BNF.

6 DATA CREATED, REGISTERED, maintained and RELEASED under the M&S Data Engineering Technical Framework shall be produced in accordance with the DATA PRODUCTION SEQUENCE.

7 DATA CREATED and EMPLOYED under the M&S Data Engineering Technical Framework shall be SPONSORED, PRODUCED, EXAMINED, ADMINISTERED, and CONSUMED in accordance with the DATA ENGINEERING PROCESS.

8 All DATA shall be REGISTERED by an AUTHORITATIVE DATA SOURCE which have been APPROVED by an appropriate Joint, Service, or Agency SPONSOR..

9 Each CONSUMER shall be an AUTHORIZED DATA CONSUMER. DATA shall not be RELEASED to any CONSUMER who is not an AUTHORIZED DATA CONSUMER.

## 7.2 Preferred Practices

1 The required CSS DATA model and associated DATA elements should be constructed in accordance with DoD 5000.59-M-1 [18].

2 DATA systems architecture implementations which support a DATA development process should:

2.1 provide an intermediate, simulation developer API, either as an OMG COSS or as a set of native high-level programming language calls, and

2.2 provide high level, simulation end-user Graphical User Interface (GUI) capability in the form of an OMG Common Object Facilities or a native windowing schema.

3 To support concurrent work-in-progress by DATA SOURCE, VV&C EXAMINER, and simulation developers, DATA from a SPONSOR APPROVED DATA SOURCE may be REGISTERED, CONVERTED, and INTEGRATED in parallel with EXAMINER activities to provide the required VV&C for AUTHORITATIVE DATA SOURCE approval.

## 7.3 Technology Extensions

1 Employ the Data Analysis and Reconciliation Tool (DART) [19] to define entity-based DATA elements.

2 Employ the CMMS Verb Dictionary [20] to define action-based DATA elements

3 Employ the Comprehensive Utilities for Data Administration (CUDA) [21] procedure for reconciling and deconflicting data elements and data models.

## **Enclosures** [TBD]

## **Annexes** [TBD]